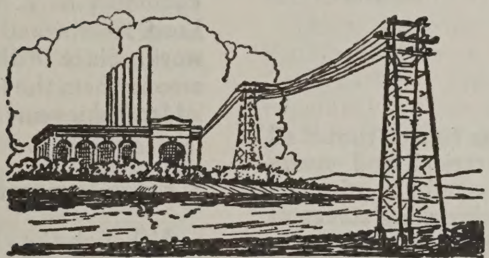
Public Welfare Service

Bulletin No. 2
(Sixth Edition)
1926

ELECTRICITY



How It Is Made and How Distributed

For Use of School Students, English and Current Topics Classes and Debating Clubs

Issued by
ILLINOIS COMMITTEE on PUBLIC UTILITY INFORMATION
79 West Monroe Street - - - - Chicago, Illinois
(Additional copies will be furnished on request)

ELECTRICITY—THE GIANT ENERGY

Introductory:

Electricity has been called the giant energy. Within the memory of men now living it has revolutionized the world. It has made possible, within half a century, greater progress than in all the 500,000 years of history which preceded it and which science gives to the career of man on earth.

Man has learned to harness, distribute and utilize this magic power for day and night service throughout the civilized world. It is banishing darkness, has lightened the burden of the housewife and has become the silent partner of industry.

The story of the development of the use of electricity is a fascinating recital. It is a story of progress. Electricity has brought about a revolution in industry, for it has enabled one man to do the work of many men, and made possible huge production in our factories, rapid transportation and better living conditions in our homes. It has built our great cities and industrial centers. It has torn away the barriers of time and distance and made all men neighbors. Through radio it has brought entertainment and knowledge to millions.

Your "Thirty Slaves:"

The Smithsonian Institution has figured that if all our machinery operated by electrical and steam power should be taken away, it would require the services of 30 times as many hardworking slaves as we have population to duplicate the work done in America. In other words, the use of power and machinery gives to every man, woman and child in our country the equivalent of 30 slaves, or the average family of five has 150 "slaves" working for it.

But instead of this army of slaves we have electricity working for us at a "wage" so small as to bring its services within reach of the poorest man's pocketbook; a sum so small that it would not pay for what a servant would eat.

Push a button and our home is illuminated as by the midday sun; an electric vacuum cleaner banishes dirt and dust; an electric washing machine and electric iron help with the housework; a fan gives cooling breezes or an electric heater radiates warmth; an electric range cooks the family meal; an electric refrigerator makes ice; or the many other familiar labor-saving appliances are placed in action.

Today, electricity rings the door bell; tows a ship through the Panama Canal; lifts a great bridge; milks the cows; chops feed on the farm; increases production in factories by providing good lighting and ample power; lights homes and stores; even provides illumination for surgical operations in hospitals. It is ready to perform these tasks 24 hours of each day.

Yet it was only a short time ago—less than 50 years—that the richest kings had none of the commonplace conveniences which make life easier and better for even the poorest Americans at the present time.

This change is due to the tremendous efforts of the nation's electric utilities.

The Great Minds of Electricity:

Many great minds have contributed to the development of the present-day electric central-station systems which provide our electricity. If only one name were to be mentioned, it would undoubtedly be that of Thomas A. Edison. But before Edison, with his marvelous inventions, and contemporary with him, a host of other electrical scientists and inventors have contributed their part.

Such men as Dr. William Gilbert, Benjamin Franklin, Luigi Galvani, Alesandro Volta, Sir Humphrey Davy, H. C. Oersted, A. M. Ampere, G. S. Ohm, Charles Wheatstone, Michael Faraday, Joseph Henry, Z. T. Gramme, J. C. Maxwell, A. Pacinotti, S. Z. deFerranti, Werner von Siemens, Lord Kelvin and many others did very important work. Since Edison's discoveries other scientists, among them the late Dr. Charles A. Steinmetz, have added achievements of great value.

Early Inventions:

Although the electric light and power business, as we know it today, is a development of comparatively recent origin, the foundations for it were laid by early experimenters in the Seventeenth and Eighteenth centuries. Back in 1600, Dr. Gilbert, an English physician, conducted numerous experiments and made many important discoveries, but it was nearly a century and a half later before any great progress was made by others who studied the subject.

Benjamin Franklin's demonstration by his famous kite experiment in 1752, proving that lightning is an electrical phenomenon, is well known. About 1790 Galvani discovered a current of electricity. Up to that time electricity had been developed only by friction. Volta developed the electric battery in 1800. Oersted of Copenhagen discovered in 1820 the magnetic effect of electric current. This paved the way for the later developments of electrical machinery. Michael Faraday of England discovered in 1831 the basic principles on which dynamo electric machines are designed. Many other scientists and inventors made important discoveries during the early part of the Nineteenth century.

The telegraph was the first great electrical invention. It was invented by Morse in 1837. Electroplating was perfected about the same time. The electric motor was developed about 1873. Radio is a development of the present generation.

The First Central Station:

Development of the electrical industry, however, really dates from Sept. 4, 1882, the day on which there was opened in New York City the first central electricity generating station in the world. This plant, known as the Pearl Street station, furnished electricity for lighting in a small territory in downtown Manhattan.

Three years before this, on October 21, 1879, Edison had invented the electric light, but until the opening of the Pearl Street station, the light had been looked upon as an impractical curiosity. When the Pearl Street station was placed in operation a new epoch in electricity was started, for this first central station utilized the same basic principles that are used today by all electric light and power companies.

This station—started a little more than four decades ago—served 59 customers. From this beginning the electric industry has grown until at the present time there are 17,937,160 customers, of whom 14,532,930 take residential lighting service. The number of customers of electric light and power companies in the United States doubled in the six years between 1909 and 1915, and doubled again in the following six years. At the present time the increase is almost 2,000,000 customers per year.

The Pearl Street station had six generators with a total generating capacity of 559.5 kilowatts. The generating capacity of all plants in the United States at the beginning of 1926 was 26,830,000 kilowatts or 35,952,200 horse-power.

The output of electricity in 1925 set a new high record, the total being 65,801,000,000 kilowatt-hours. The Commonwealth Edison Company, which serves Chicago, in 1925 had an output of 3,091,424,000 kilowatt-hours, the largest production of any steam central station company in the world. An illustration of the rapid development of the electrical industry is shown by the fact that the Commonwealth Edison Company had a generating capacity of only about 640 kilowatts in 1888. In 1925 it was 886,000 kilowatts.

Today the electric light and power industry represents an investment of approximately $7,500,000,000 and about $800,000,000 is spent annually for new plants and extensions to meet the ever-increasing demands for service. The gross revenue of the electric light and power companies of the country in 1925 was $1,475,000,000. The industry is owned by over 2,500,000 men and women investors, banks, insurance companies and others, whose money provides funds for building the great systems whose services are available to all of the people.

Where Electricity Comes From:

Electric light and power service starts at the central generating plant—called the "central station"—where electric energy is produced in large quantities. From these central stations wires carry the energy to the homes, stores and factories of the nation—to provide illumination, to turn the wheels of the machines in factories, to operate electric railway cars and to help the housekeeper by supplying energy for her vacuum cleaner, toaster, flat iron, washing machine and other appliances.

Electricity is produced most economically in central stations where large generators are used, and it is transmitted and distributed at much less expense if all of the electrical needs of one large community, or several small communities, are supplied from one common system of wires. Therefore, the modern tendency is to replace small generating stations with substations, which are distributing stations for the large systems. This gives the benefit of the economies of the large stations to small communities.

There are two kinds of electricity made and distributed by a central station—"direct" and "alternating." Direct, or continuous current, flows constantly in one direction. This kind of current, because it cannot be sent any great distance, is used largely in the congested centers of populous cities. Alternating current flows first in one direction, then reverses, but so fast that the changes cannot be detected in an electric light by the naked eye, except in low cycles, in which it is visible. This has resulted in adoption of a general standard of 60 cycles for lighting. Alternating current can be sent, economically, hundreds of miles, and, therefore, is now used almost universally.

How Electricity Is Made Available:

Electricity is produced from some form of heat energy, as that obtained by the combustion of coal, oil, gas or wood; from some form of mechanical energy like that of falling water or (to a slight ex-

Statistical Data Showing Development of Electric Light and Power Industry in the United States During the Last 24 Years

	1902	1912	1920	1922	1923	1924	1925
Capital Invested	$504,740,352	$2,175,678,266	$3,688,597,000	$5,100,000,000	$5,800,000,000	$6,600,000,000	$7,500,000,000
Gross Revenue	78,735,500	302,273,398	932,000,000	1,084,000,000	1,300,000,000	1,350,100,000	1,475,000,000
Capacity in Kilowatts	1,212,200	5,165,439	13,000,000	17,725,484	18,558,800	18,840,000	26,830,000
No. of Customers (Total)	1,465,060	3,837,518	9,597,997	12,353,790	13,710,000	16,377,605	17,937,160
Residence			7,465,900	9,903,830	11,030,000	13,252,985	14,532,930
Commercial			1,744,500	1,988,020	2,205,000	2,524,705	2,781,280
Power			387,597	461,940	475,000	599,915	622,950
Total Generation in Kilowatt-hours	2,507,051,515	11,569,109,885	40,288,264,000	44,084,575,000	51,498,450,000	59,013,590,000	65,801,000,000

tent) wind power, or from chemical energy, as in batteries. In the case of water-power plants the momentum of the falling water is used to revolve waterwheels which in turn operate electric generators. The water may be small in volume but have a great pressure because of a high fall, or it may have low pressure and much volume, or have any combination of these qualities.

The most desirable class of streams for water power developments are those having a fairly constant flow throughout the year. This covers a comparatively small number of streams. Next in desirability are those having a large portion of the maximum water flow available during most of the year.

Utilization of these streams is expensive as water-storage facilities are necessary to keep water available throughout the entire year.

Then there are "flashy" streams—erratic and experiencing sudden and short flood periods with intervening periods of little or no water. They are uneconomical for development. This class includes many Middle Western streams.

Water power development also may be uneconomical if the proposed site is so far from the power market as to make necessary an extremely expensive transmission line, or because of large power losses through transmission over a great distance. Because most of the streams in Illinois are in the "flashy" class very little water power has been developed in this state, less than 4 per cent of the electricity being produced in this manner.

Sometimes electric generating plants are built right at the coal mine in Illinois and other states. This is seldom practical, however, as efficient operation of turbines requires from 500 to 700 tons of water for every ton of coal burned to chill the condenser tubes and to condense steam after it has done its work in the turbines.

In New York, Chicago, Philadelphia, Boston, and other large cities, more water is pumped for condensing purposes in electric generating stations than the city water-works pump for all other purposes. This need of an abundance of water is an outstanding reason why more generating plants cannot be built at the mouths of coal mines, where there is seldom a large supply of water.

At the central station the coal is handled by mechanical conveyors and crushers, themselves operated by electricity, and is delivered to the automatic stokers of the furnaces without being touched by human hands. The other raw material required—if brains, labor and capital are not raw materials—is water. This is delivered to the boilers, where the heat of the burning coal converts it into steam. The steam is piped to the turbines where the impact of its expansive force and its momentum rotate the shafts of the electric generators.

The Turbine:

The principle of the steam turbine is very simple. It is practically the same as the water turbine, and the water turbine is only an elaborated water wheel. The latter receives its power from water pressure of rivers or reservoirs of water so stored that when the water flows it strikes the blades of the wheel rotating it and producing power, because of the pressure back of it. In like manner steam generated in central station boilers by coal is directed against the blades of a steam turbine which rotates from this impact, perhaps 1,800 times a minute, and produces power. These turbines—"electric machines" or generators, as we now call them—are attached directly to the shaft without the use of belts.

The energy we have so far pictured as being created in a central generating station is mechanical and not electrical energy, but right here, in the generator, the transformation takes place. The power that goes into the turbine as mechanical energy is taken from the generator at the other end of the shaft as electrical energy.

In spite of the enormous power produced by a modern generator, the principle of its work is based on simple laws. Early experiments by the famous Faraday (born in England, 1791) marked the beginning of the electric generator, and the same laws that Faraday worked out are applied to the making of the huge generators of today. Nothing of importance has been added except elaboration of machinery. Faraday used a coil of wire and a magnet. Each time the magnet was thrust into the coil its magnetism was found to cause a flow of electricity in the coil, as indicated by a compass placed near the coil of wire. The same phenomenon takes place when a generator rotates. It contains magnets and coils of wires, which are, of course, much stronger than those used by Faraday. As long as the magnet rotates inside of the coil, electricity is generated. Nowadays the turbine and the generator are so closely related that they are made by manufacturers in one complete unit known as a "turbo-generator."

The electricity which comes from the generators is so powerful that it must be controlled very carefully. This is accomplished by means of copper switching devices. Copper is used because it is one of the best conductors of electricity, and relatively cheap. Alternating current is often raised to high voltages, because at high pressure it can be economically transmitted long distances by comparatively small copper wires, and its voltage can be changed by transformers. Direct current is not adaptable for this long-distance, high-voltage transmission, and its voltage cannot be changed by transformers.

The Transformer:

Although high voltages are necessary for transmission lines, electricity is generated and is used for lighting and power purposes at low voltages.

Transformers are used, therefore, to "step" the voltage up as the current comes from the generator and to "step" it down when it leaves the transmission line. Sometimes huge transformers are used in "sub-stations" from which energy is distributed to large sections of a city or to small towns. The transformers, which are a familiar sight on poles in streets or alleys, finally reduce the pressure to a safe point for domestic use and send it into the dozen or more houses in the midst of which the transformer is located.

The Basic Laws of Electrical Energy:

Something very interesting takes place within the transformer and if our eyes could see electricity we should see a remarkable phenomenon going on all the time in each one of these little iron boxes. We have already noted above, in connection with the generator, that when a piece of magnetized iron was moved through a coil of wire electricity was produced. Early experimenters found another truth which naturally followed: viz., that when electricity flowed through a coil of wire around a piece of iron magnetism was produced in the iron. These two principles taken together illustrate how a transformer works. Suppose we think of electrical energy as it travels from the power station along transmission lines into the transformer box. There it runs into a coil of wire which surrounds a piece of iron. The electricity in the coil magnetizes the iron and the magnetized iron in its turn produces electricity in another coil, which is around the magnet but entirely separate from the first coil. The pressure in the coils is proportionate to the turns of wire. The more wires in either of these two coils the more pressure we have; therefore, if one coil has ten times as many wires as the other, or "secondary" coil, the pressure at the other, or "secondary," side of the transformer will be reduced to one-tenth of what it was when it entered it.

From the other side of the transformer electricity is led at low pressure into the house or factory through a service switch where it can be turned on or off, and then through a meter, which measures the current. After that it is available for toasters, irons and the dozens of other household uses. In the case of the large neighborhood substations power taken from the secondary side of the large transformers is often used to operate street railways or street lighting circuits.

How Electricity Has Revolutionized Industry:

Electricity has made America machineland. There are not less than 3,000 uses for electricity. Most of them are in industry, but the use of electricity for power, as well as for lighting and heating in the home, is growing steadily.

Although the use of electrical energy for driving motors is its most common employment in industry, aside from illumination, it is being used more and more for generating heat and bringing about chemical reactions in many manufacturing processes.

In the latter field electricity has a wide use in electro-chemistry, a department of industrial endeavor with which most people are not familiar. In electro-chemistry, electricity is used to break down, build up, cover, uncover, separate and blend. Some remarkable accomplishments result.

These are probably better understood by reference to the experiment conducted in school laboratories of reducing water to its component parts, hydrogen and oxygen, by passing an electric current through it. That is an example of breaking down. Electro-plating is an example of the building up process. In electro-plating, copper plates are immersed in a solution of silver nitrate and by passing current through the solution, silver is deposited on one of the plates.

There are many other reactions brought about by electricity on a large scale which are the bases of the electro-chemistry industry. Eighty per cent of the copper produced in the United States is separated from ore by electricity. Gold and silver are separated from the ore in the same way. Aluminum, nickel and silver are "recovered" from ore and waste. Almost all gold plated jewelry is gilded by electrolysis.

Use of electricity for smelting ore is a comparatively recent development. Making of "electric steel" is a fast-growing industry.

By using electricity, vanadium and chrome—new kinds of steel—were produced. These are used for automobile and airplane parts and for castings where a perfect texture is necessary. Electric steel is also utilized in making tools such as drilling bits which must stand hard usage.

Electricity as a Producer of Heat:

Electric heat is being applied to iron, nickel, copper, silver, brass and bronze and other nonferrous metals. Electric furnaces produce such electro-chemical "mysteries" as ferro manganese, silicon, tungsten, molybdenum, chromium and titanium, abrasive materials such as carborundum, alaxite and magnesite.

During recent years electricity has been used for operating electric ranges to a very great extent in those communities which do not have gas available. Through perfecting of this appliance the housewife in the smaller community is able to cook as efficiently, cleanly and with the same degree of comfort as is possible in the larger cities. In Illinois there are more than 6,000 electric ranges in use at the present time.

Electricity is being used extensively in coal mining. In Illinois, alone, hundreds of mines purchase all or part of their power from central stations. Formerly, when coal mine operators generated their own electricity, 20 pounds of coal were burned to produce one kilowatt-hour. As modern central stations produce this same energy with only 2 pounds of coal, a great conservation of fuel has taken place and the cost of power used in mining coal has bee lowered.

Future Development of Railroad Electrification:

One of the great developments of the future will be the more general electrification of steam railroads, as the experimental stage of this use of electricity seems to be passed. In several cities in the United States the railroad terminals have been electrified, and through Montana, Idaho and Washington one large steam railroad has electrified its tracks for 600 miles over mountains. Four-thousand-ton trains go up and down steep mountain grades under perfect control at speeds never attained under steam

operation, and with a regularity that leaves no doubt as to the practicability of electrification. All railroads leading into New York City are electrified within the city limits.

In Illinois, the Illinois Central Railroad has electrified its tracks used for suburban service, and is working on a general electrification program for its entire terminal facilities. When first placed in operation the electrification comprised from two to six parallel tracks extending thirty-five miles from the Randolph street terminal, and, with two electrified branch lines, made a total of 125 track miles. When completed, there will be as many as fifteen parallel tracks electrified, and in all there will be about 400 miles of track equipped for electric trains.

Power Obtained from Central Stations:

When the Illinois Central Railroad's management planned for electrification of its Chicago terminal, it had expert engineers investigate a supply of power for the project. They reported that power could not only be purchased cheaper from electric light and power companies than it could be generated by the railroad, but that a purchased supply was much more reliable. Seven sub-stations, provided by the central station companies serving Chicago and vicinity, supply the railroad with power for the operation of its trains, for its signals, and for its repair shops.

Has Many Advantages Over Steam:

Some of the advantages to the public of electrified steam railroad suburban service are greater comfort, speed and frequency of service; extension of suburban residence districts, thus making available a greater number of attractive home-sites; increase in value of real estate; beautifying of residential and shopping districts; advertising value to the city as a whole; elimination of the smoke nuisance; lessening of noise nuisance; making possible sub-surface operation of trains, which opens a way for through streets and lessens traffic congestion; and aiding the growth of small suburban towns by making them more a part of the big city.

Engineers say that if all steam railroads were electrified and energy furnished by coal-burning generating stations, 136,000,000 tons of coal would be saved each year. If hydro-electric generating stations furnished one-third of the electricity, 162,000,000 tons of coal would be conserved each year.

Farm Electrification:

Electric light and power companies are devoting much time and effort to the electrification of farms in the belief that electricity will increase the productivity and the earnings of farm workers and make their life more pleasant, as it has done these things for residents of towns and cities.

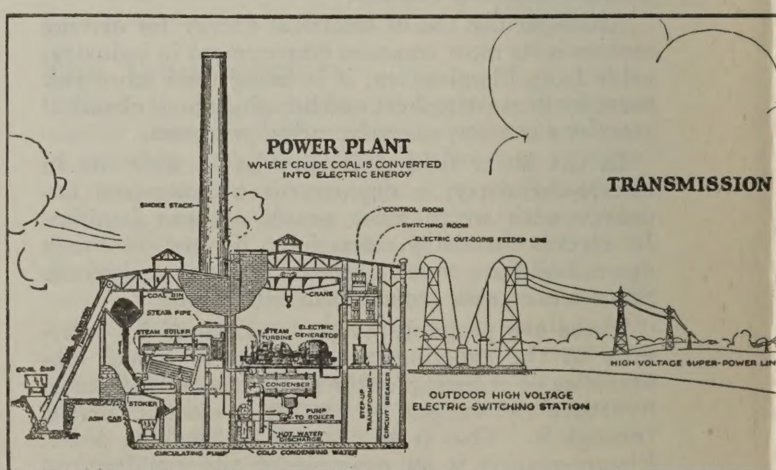
The use of electrically-operated labor-saving machinery has made the American worker the best paid worker in the world. The American farmers use more machinery and produce more per capita than do farmers in any other country. The tendency is towards the use of mechanical and electric power in place of man-power and animal-power.

The value of electricity on the farm is determined by both its economic advantage and its betterment of living conditions. From an economic standpoint, its value is measured by the labor displaced, increased production, and reduced cost of operating the farm. Its other value is that it makes farm life more pleasant, keeps the boys and girls from leaving for towns and cities, and gives to the farmer a pride and satisfaction that cannot be measured. Also, it opens up profitable lines of farming, which many farmers avoided because of the large amount of labor involved. Dairy farming is one of these farm activities which is made easier by electricity. Milking can be done electrically, the separator can be operated by an electric motor, and the milk and cream kept fresh and sweet in an electric refrigerator.

Farm Electrification Experiments in Illinois:

On ten farms near Tolono, Illinois, where there is a large diversity of operations and products, the University of Illinois is conducting experiments in rural electrification. Electric light and power companies of the state, farmers' organizations, and manufacturers of farm machinery and electric appliances are cooperating with the school. Accurate records of the cost of electricity used and the value of the products are kept. Electricity is being used in dairying, poultry raising, stock farming, grain farming, seed production and general farming. It is believed that these experiments will bring about a more general use of electricity on Illinois farms.

Among the uses which have been found for electricity on farms are: grain elevating, ensilage cutting, feed grinding, grain cleaning, grain threshing, hoisting hay, milking, mixing concrete, pumping water, refrigeration, sawing, sawing wood, cream separating, auxiliary heating, brooding chicks, incubating chicks, cooking, ironing, water heating, barn ventilation, corn shredding, corn shelling, timber utilization, dish washing, and lighting of houses, barns, poultry houses and out-buildings.



Already many farms have electricity delivered to them by the central station plants and it is to be expected that within a short time the rural districts will have the same efficient and modern service as is possible in the thickly populated cities. As farmers develop more uses for electricity, the extension of service will be more rapid.

What an Electrical Map of the U. S. A. Would Look Like:

If one could see, upon a map of the United States, outlines of systems for generating, transmitting and distributing electricity the impression would be something like that of seeing a number of interconnected spider-webs, each large generating station being the center of its own web. Each system may have several generating stations, the whole network being tied together in such a way that the breakdown of a machine in one generating station or the failure of a substation would not, usually, mean loss of service to the customer, other sources of supply being available in emergency.

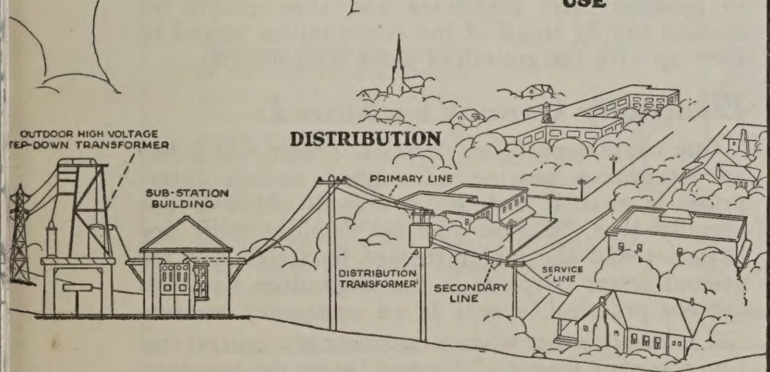
The same plants that serve the cities now furnish service to the smaller communities and to the farms. They are no longer local distributors, but reach out as far as their wires are strung. One company, alone, may serve hundreds of communities from its central station energy-producing plants. That is why the rendering of service is now regulated by the state. It has outgrown its original city boundaries.

The Illinois Superpower System:

The first electric generating stations and distribution systems were constructed in large cities, such as Chicago and New York, about 40 years ago.

At first many small stations were constructed in the same city to serve very restricted areas which did not exceed two miles square. The art of generating and distributing electric energy advanced rapidly so that about 15 years after the completion of the first plants we find that in the large cities many of these small plants were superseded by large generating stations which supplied the entire community.

About 25 years ago small central stations were built also in communities of 5,000 population and larger. Residents of smaller communities and farmers did not have electric service, for developments in the electric art did not permit their having service without incurring a financial loss to the electric companies. Therefore, a large portion of the people in the United States did not have electricity available.



Early Systems Small:

The early systems in most small and medium-sized towns did not operate 24 hours per day but only at night from dusk to dawn, as practically the entire business supplied in those days consisted of lighting.

About 25 years ago the electric motor was coming into general use. Where the demand for electricity for motors was large, the central stations found it profitable to supply electricity the entire 24 hours of the day. However, in many small communities there were not enough motors used to pay the expenses of electric service during the day-light hours.

The generating stations of 15 to 20 years ago in small and medium-sized communities were expensive to operate and the rates charged for electricity were high compared to rates of the present time. Many stations charged 20 cents per kilowatt-hour, which seems ridiculous today—although this rate is still charged in some towns in Illinois where modern equipment is not used.

About this time rapid strides were made in the development of the steam turbine. It was found that the turbine could be made in large sizes having greater generating capacity than was possible in the old-style reciprocating engine. Also, it was found that the turbine generated a kilowatt-hour of electricity with less coal.

Transmission Line Systems:

This economy in operation made it plain that the way to best serve the small community was by generating electricity in large, economical central stations, and carrying it to the small town over high-voltage transmission lines. As this was accomplished the small communities and many farms received the same electric service as was heretofore had only in large cities. They had 24-hour service and rates which were much lower than when the small, isolated station supplied their power.

In this manner thousands of communities having dusk-to-dawn service were supplied electricity throughout the entire day, and additional thousands of villages and small towns which were too small to support their own generating station were given service for the first time.

In no section of our country has this great development been more marked than in Illinois. Before the days when transmission lines were built, electric service was available to only about 200 communities, and in the majority of cases only for part of the 24 hours.

Illinois Stands High:

At the present time, after a ten-year period of continuous construction of transmission lines

throughout the state by many public service companies, electric service is being rendered to more than 1,200 organized communities, 82 per cent of which are served by transmission lines and are receiving 24-hour service. Many of the smaller communities, which are served by isolated generating stations, still have electricity available only part of the day.

There are about 7,100 miles of high-voltage transmission lines in Illinois. The predominating voltage of these lines is 33,000, although some are as high as 132,000. Branching off from these great energy lines are thousands of miles of lateral wires which bring the electricity to the user.

On January 1, 1926, there was installed and in operation in central stations of the state 1,511,897 kilowatts or 2,025,941 horsepower of generating capacity.

Each customer of the central stations in Illinois uses, on an average, 3,292 kilowatt-hours of electricity annually.

Illinois ranks second among the states in the number of electric customers served by central stations. It had, on January 1, 1926, 1,582,550 customers, of which 91,073 were added during 1925. The state ranks high, also, in the degree of saturation of lighting customers, 73.2 per cent of the homes being wired for electricity.

Although Illinois has but 6.1 per cent of the population of the United States it has 9 per cent of the electric customers.

Superpower in the Middle West:

Superpower, or the inter-connection of large generating stations by high-voltage transmission lines, is not a development of Illinois alone. It is a development of areas whose boundaries are fixed by geographical barriers or economic conditions and not by state lines.

Illinois' great generating stations and transmission lines are part of a vast superpower system extending from the Dakotas to West Virginia, and including Ohio, Pennsylvania and Kentucky. Thousands of communities in these states are linked together.

This continuous, rapid hooking up of smaller systems gives rise to the belief that formation of one great superpower system extending from the Atlantic ocean to the Rocky Mountains is not far distant.

Big Benefits Obtained:

Illustrative of the economy of large generating stations is the saving of fuel. Small, isolated generating stations burn about 15 pounds of coal to generate one kilowatt-hour of electricity. The large stations, such as are a part of the superpower system, consume, on an average, only 2 pounds of coal per kilowatt-hour. This is important when it is considered that 96 per cent of the electricity generated in Illinois is made from coal, practically all of which is mined within the state.

The benefits of this great gain in efficiency have been given to the customers in the form of lower rates than those originally charged by the smaller plants, 24-hour service to all communities served and adequate power supplies for industries at reasonable rates. Notwithstanding the fact that coal today costs 95 per cent more per ton than in pre-war times, the average rates now charged are very much less than the average rates ten years ago in these same communities. If such systems had not been constructed, the average rates now prevailing would be at least 50 to 80 per cent higher in order to pay the cost of operating the smaller, inefficient stations.

Inter-connection Assures Continuous Service:

Another advantage of superpower is that it insures a continuous electricity supply to communities, even in an emergency.

Should a tornado, earthquake, fire or other catastrophy put out of service the generating station of a community which is a part of a superpower system, other communities in the system, even though many miles away, could each furnish the stricken town some electricity and the aggregate power thus furnished would enable the place so disabled to "carry on". This has been done many times.

The importance of this protection is realized when it is considered that in many towns water for fire protection and sanitation is pumped by electricity.

Also, a sudden, large demand for electricity, such as for irrigation pumps during a severe drought, can be met by superpower.

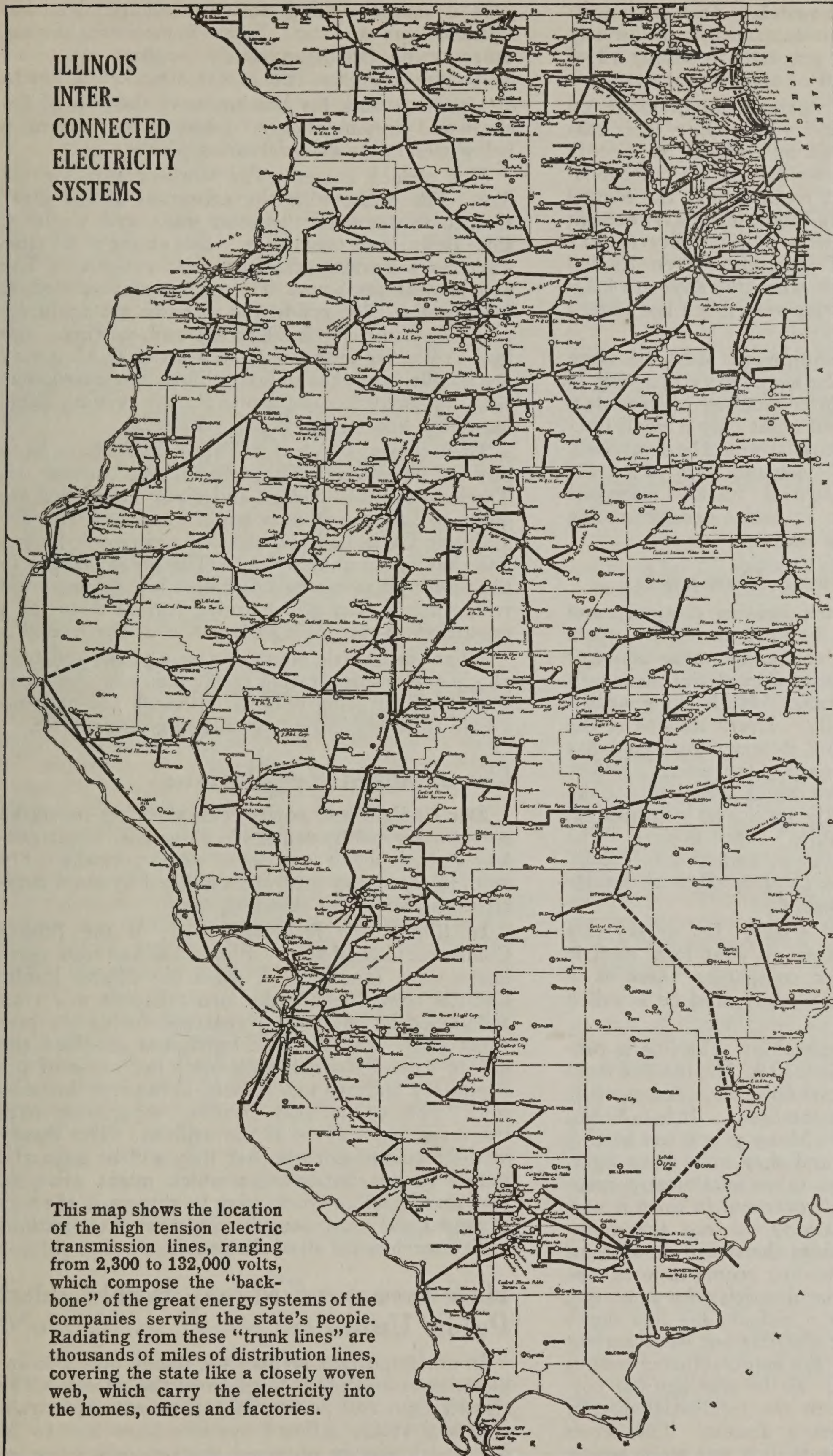
After most of the existing transmission systems in Illinois have been inter-connected, and the loads served by these systems continue to increase to much larger amounts, there will undoubtedly be constructed new, large-capacity, high-voltage trunk lines, or true superpower lines, which will serve as feeder lines to the existing transmission systems at a large number of intersecting points. Such superpower lines will receive their supply of energy from very large central stations of the most efficient type, and the development of such a system will enable the more inefficient stations still operating to be discontinued gradually. The existing transmission lines will then occupy the relative position of primary distribution lines, with the new trunk lines serving as the transmission source. Such a development will not render useless any of the systems now in service, but on the contrary serve to increase their usefulness and thus enable increased supply to all of the communities served to keep up with the growth of these communities.

Electricity Cannot be Stored:

One characteristic of electrical power which has an interesting bearing on central station enterprises is that it cannot be stored. This is not literally true, because you are familiar with dry batteries and the larger storage batteries, but for general power purposes in the large cities batteries are not practical, except as an emergency reserve.

The result is that when a customer of a central station company makes a "demand" upon the company

ILLINOIS INTER-CONNECTED ELECTRICITY SYSTEMS



This map shows the location of the high tension electric transmission lines, ranging from 2,300 to 132,000 volts, which compose the "back-bone" of the great energy systems of the companies serving the state's peopie. Radiating from these "trunk lines" are thousands of miles of distribution lines, covering the state like a closely woven web, which carry the electricity into the homes, offices and factories.

Illinois' electric power supply systems are a part of the great net-work of superpower lines that pool the energy resources and needs of thousands of communities in an area extending from the Dakotas to West Virginia, and which includes Pennsylvania, Ohio and Kentucky.

Illinois is the center of the world's greatest power pool.

for electricity by turning a switch, the company must be prepared to supply this demand instantaneously and it must likewise be prepared to supply all of the simultaneous demands of all of its customers.

Unfortunately central stations cannot make up in advance enough electricity to supply their customers for a day or a week or a month, as a store stocks up with goods in advance of its customers' demands. This very fact requires that the central station maintain a plant and equipment large enough to deliver the huge amounts of electricity for the dark and busy days of December, even though during the month of June, when the days are long, a much smaller plant costing very much less money might suffice.

Similarly plant and equipment must be large enough to take care of the very heavy demands of the late afternoons of winter months, whereas during the rest of the day and night only a small fraction of that amount of electricity would be demanded. These highest points of "demand" are called the "peak load" and the central station managers always have to figure on investing enough money to take care of the "peak load."

Watching the Service Demand:

Let us go to the electric lighting company and see just how electricity is made to do its work. We walk into the office of the operating manager of one of these companies. One of the manager's duties is to watch the traffic. He is the guardian over the flow of electricity. Every minute of the day he can tell something interesting about what the citizens of his community are doing. Before him he has a long sheet on which lines indicate the rise and fall in the use of the service he is furnishing. His fingers are on the "pulse" every minute. The line which he is watching is called the "load," which simply means the total amount of service being used at a given moment.

We will watch him for a day. Let us say this particular man is manager of your local electric company. In the larger companies there is a man assigned to this work solely, and he is called the "load dispatcher."

It is 5 o'clock in the morning. The line is running along straight. It is 5:30 A. M.; the line commences energetically to start upwards. Some people are rising and turning on the lights. It is 6 A. M.; the line has shot far up. Many people are getting up, but it is still dusk, and they must have light. It is 7 A. M.; the line has taken an almost perpendicular upturn. Practically everyone in town is now up; some are using electricity to read the morning paper, some for cooking; the street car systems have put on many cars hauling people to work; the industries have turned on electricity for operating the big machines. It is 8 o'clock; his line shows that out in the residence districts but little current is being used now, but in the manufacturing centers the load is tremendous. So he watches the current that started to go to the residential district shift to the manufacturing district. The street car load is much less now than it was while people were going to work.

It is midday. The residential district load has "picked up" a little. Some women are ironing, others using sewing machines, washing machines, or vacuum cleaners, still others are cooking lunch.

Afternoon sees his line up near the top of his sheet and keeping steady. Most of the current is being used in the manufacturing plants.

Five o'clock comes. The workers quit for the day. The mills, with the exception of the great electric furnaces in the steel mills and smelters, close down their machinery. But at the same time has come a great demand from another source. The people must get home. The transportation electric load swells. The residential districts are again demanding electricity for lighting and cooking. His load shifts over to that side. Up until 6 P. M. it may sag a trifle, while the industrial load has eased, but then the great demand comes for the evening lighting of the homes, and it picks up again.

Then comes 9 o'clock. The children have been put to bed. Many lights have been turned off. The load sags; 10 o'clock and many grown-ups are going to bed and it sags more; 11 o'clock and the majority are in bed and the demand now is far below that of an hour before. The great engines in the power plant can be eased up a bit, given a little rest, when repairs and cleaning can be done for a repetition of this giving of service in the morning.

What the electric manager saw, the gas and telephone and transportation traffic men saw similarly, their lines changing only to represent the happenings in their particular branches of giving service.

Government Regulation:

Electric light and power companies are regulated as are other public utilities such as gas, street railway and telephone companies. In practically every state in the union they are regulated by state commissions created for that purpose.

In Illinois the regulatory body is the Illinois Commerce Commission. Illinois has had state regulation since Jan. 1, 1914, when the Illinois Public Utilities commission came into existence under an act passed by the state legislature during the previous year. In 1921 the legislature modified the law to some extent and changed the name of the regulatory body to the Illinois Commerce commission. This commission exercises supervision over the rates and service of the utilities. The theory of these commissions is that they will be impartial judges in all controversies which might arise, so that no stumbling blocks may be thrown in the way of proper and continuous development of the various utility services for all of the people.

How Investors' Money Builds Public Utilities:

In one important respect the public utility is unlike almost any other business in the nation. The electric light and power, gas, telephone, street railway and steam railroad systems have had to be built with money obtained continuously from investors. Under the prevailing system of regula-

tion they can make no "profits" in the sense other businesses do.

They are allowed to charge only such rates as will permit the earning of operating expenses, plus a fair return on the money invested in their properties. Consequently all additions and extensions must be financed by the sale of new securities to thrifty investors.

Whereas, in ordinary businesses — dry goods business for example — the merchant may reasonably expect to turn over his capital (buy and sell a complete stock of goods) three to five times each year, the utility business receives from its customers, each year, approximately one-fifth of the money its property represents.

The most common form of financing utility companies is through the issuance of bonds—which are mortgages on the actual property—to the extent of 50 to 60 per cent of the value of the property; and through the sale of preferred stock, on which there is a definite, fixed earning or dividend rate, to a total of about 25 per cent of the property value; and through sale of common stock, which is income-bearing only from earnings accruing after payment of bond interest and preferred stock dividends, to the value of the remainder of the property holdings.

Elements Other than Equipment Back Service:

Service of these commodities necessary to modern life does not begin, nor end, with the mere installation of power plants, distributing plants, the maze of equipment, nor the building up of great bodies of employes as the operating forces. There are three fundamental elements back of all this:

1. Individual brains: This is personified in the man who sees the possibilities of rendering service to a community; who devotes his time, experience and brains to skilfully planning that service to meet needs; who interests people having money in his "big idea," organizes a company and gives the public the benefits of his initiative.

2. The investors: Those thrifty persons who save part of their earnings with which they purchase stocks and bonds of the company with the expectation that the company will succeed and earn them a fair return on their savings—the people whose money makes possible the extension of service for the prosperity and welfare of the community.

3. The inventors: The geniuses who made possible the great machines and wonderful apparatus that is necessary to produce service and who are striving constantly for improvement, they too expecting financial reward for their labors.

Schools Now Hold Generations That Must Carry on the Utilities:

These three elements of service form an unbreakable chain. All three are interdependent. Should anyone of them become discouraged, development would immediately lag and the nation would be the loser.

In the schools today are those who in the future must "carry on;" who must soon be in the harness working out the problems of light, heat, transportation and communication for the nation and the world; problems that will be no less complex than those which the great pioneers have faced. The tremendous fight of the pioneers—those of the ' first generation," the men with the vision—who convinced the world that such "absurdities" as electric lighting, electric power, street cars that moved by invisible power, telephone wires that could carry a voice over unlimited spaces, gas that could actually be piped and made to cook, heat and operate great factories, were in reality possible, and through overcoming incredulity and actual superstition made possible a revolution of home, commercial and industrial life, has not ended. Within the next ten years the demands of the nation for service will probably be double those of today as a result of the more complex civilization, increase in population and need of more intensive and economical production.

Definitions of Electrical Terms:

AN OHM:—

The practical unit of electrical resistance. It is named for G. S. Ohm, the German scientist.

Illustration: The difficulty with which water flows through a pipe is determined by the size, shape, length and smoothness, etc., of the pipe. This difficulty with which current flows along a wire is determined by the size, length and material of the wire. The electrical resistance is measured in ohms.

AN AMPERE:—

A unit of measurement to determine the rate of flow of electric current along a wire. It is named after A. M. Ampere, French mathematician.

Illustration: The rate at which water flows through a pipe which may be checked by opening any faucet and measuring what comes out is generally measured in gallons per minute. The rate of flow of electric current is measured in amperes.

A VOLT:—

A volt represents the force required to cause a current of one ampere to flow when applied to a circuit of unit resistance. The name is derived from Volta, the Italian physicist.

Illustration: The flow of electric current in a single circuit is just about the same thing as the flow of water through a pipe. The three principal elements are found under practically identical circumstances, namely, pressure imposed to induce flow; rate of flow and resistance to flow. Pressure exerted to send electricity along a wire is sometimes known as "electro-motive-force" and is measured in volts.

AN ELECTRO-MAGNETIC UNIT:—

A system of units based upon the attraction or repulsion between magnetic poles, employed to measure quantity, pressure, etc., in connection with electric currents.

A WATT:—

A watt is the unit of electrical power produced when one ampere of current flows with an electric

pressure of one volt applied. A watt is equal approximately to 1/746 of one horse-power, or one horse-power is equal to 746 watts. It derives its name from James Watt, a Scottish engineer and inventor.

A KILOWATT:—

A unit of electric power, equal to one thousand watts, especially applied to the output of dynamos. Electric power is usually expressed in kilowatts. As the watt is equal to 1/746 horse-power, the kilowatt equals 1000/746 or 1.34 horse-power.

Kilo is of Greek origin and means one thousand. A kilowatt is one thousand watts.

A KILOWATT-HOUR:—

A kilowatt-hour means the work performed by one kilowatt of electric power during an hour's time.

HORSE-POWER:—

A unit of mechanical power; the power required to raise 550 pounds to the height of one foot in one second, or 33,000 pounds to that height in a minute. Horse-power involves three elements: force, distance and time. If we express the force in pounds and the distance passed through in feet, it is the solution of and the meaning for the term "foot pounds." Hence a foot pound is a resistance equal to one pound moved one foot.

James Watt, the inventor, was asked how many horses his engines would replace. To obtain data as to actual performance in continuous work, he experimented with powerful horses, and found that one traveling 2½ miles per hour, or 220 feet per minute, and harnessed to a rope leading over a pulley and down a vertical shaft could haul up a weight averaging 100 pounds, equaling 22,000 foot pounds per minute.

To give good measure, Watt increased the measurement by 50 per cent, thus getting the familiar unit of 33,000 minute foot pounds.

HORSE-POWER, ELECTRIC:—

A unit of electrical work, expressed in watts. It is equal to 746 watts. To express the rate of doing electrical work in mechanical horse-power units, divide the number of watts by 746.

ELECTRICAL CURRENT:—

Current is the term applied to a flow of electricity through a conductor.

DIRECT CURRENT:—

Direct or continuous current flows constantly in one direction. Because of this it cannot be sent any great distance, hence its use is limited to congested centers of thickly populated cities. It can be stored in storage batteries and so is advantageous for emergency use from such sources of supply.

ALTERNATING CURRENT:—

Alternating current flows first in one direction, then reverses, but in commercial circuits the alternations are so fast that the changes cannot be detected in an electric light bulb by the naked eye. Alternating current can be sent economically over comparatively great distances, and, therefore, is now used almost universally.

THE PART ELECTRICITY PLAYED IN THE MAKING OF THIS BOOK

The type—Set by an electric machine.

The illustrations—Electricity furnished the bright artificial light, drying heat and current used in the engraving process.

Electrotypes—Made by electrically depositing copper on wax moulds.

The Printing—The presses were run by electricity.

Folding—An electric folding machine saved hours of hand-labor.

Binding—The machines that stitched the pages were run by electricity.

Cutting—Electric paper cutters trimmed the pages to the proper size.

How to Use This Bulletin:

NOTE—There are four ends of speech, or in other words, four purposes for which men speak: first, to make an idea clear; second, to make an idea impressive; third, to make men believe something, that is, to convince; and, lastly, to lead men to action.

Rhetoric, Oral English, and Current Topics Classes: Suggested topics for theme writing; Oral English and Current Topics discussions.

1. To Make an Idea Clear:

Describe the Electrical Equipment of this Community.

2. To Make an Idea Impressive:

A—The New World Created by Electrical Inventions.

B—The Influence of Superpower or Interconnection of Electric Transmission Lines on the United States.

3. To Convince:

Debate. Resolved: That Electricity Has Had a Greater Effect Upon Human Life Than Have the Railroads.

4. To Secure Action:

Make Our City the Best Electrically Equipped City in the State.

Other Topics:

1. An Electrically Equipped Home.
2. Some New Uses for Electricity.
3. A Short Story of Edison's Life.
4. Possibilities and Limitations of Electricity Generated by Water Power.

Debate:

1. Large Central Station Systems Are Preferable to Many Smaller Plants.
2. Thomas A. Edison Is America's Greatest Inventor.